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# HIGH FIBER COUNT OPTICAL FIBER CABLE WITH BUFFER TUBES AROUND CENTRAL STRENGTH MEMBER

## Field of the Invention

The invention relates to optical fiber communication cables comprising buffer tubes which loosely receive optical fiber ribbons and which are disposed around a central strength member and particularly, to such a cable with a high optical fiber count and with a relatively small diameter.

## Background of the Invention

There are various types of optical fiber cables including what are sometimes called a single tube cable, a loose tube cable and a slotted core cable. In a single tube cable a tube of plastic or other material has its axis coaxial with the cable axis and loosely receives individual optical fibers or optical fibers in side-by-side relation in one or more ribbons. Usually externally of the tube, such as in a cable jacket which encircles the tube, there are strength members used to resist tensile and compressive forces applied to the cable.

In a so-called loose tube cable, there is a central strength member for resisting such forces and a plurality of plastic tubes, known as buffer tubes, are wound around the strength member, either helically or in reverse oscillating or S-Z lay.

The buffer tubes loosely receive individual optical fibers or optical fibers in side-by-side relation in one or more ribbons. The buffer tubes are encircled by one or more jacketing layers which may or may not include, encircle, or underlie strength members.

A slotted core cable usually has a core comprising a central strength member embedded in a plastic body with circumferentially spaced, outwardly opening, longitudinal

slots which loosely receive individual optical fibers or optical fiber ribbons. The core with the optical fibers is encircled by a jacket.

There is a need for optical fiber cables containing a large number of optical fibers, i.e. having a high fiber count (HFC). There are many factors to be considered in the design of high fiber count optical fiber cables. See, for example, the article entitled "The Status and Future of High Fiber Count Cable Designs" by Logan et al and published in the International Wire & Cable Proceedings 1999. Thus, cable size, weight, stiffness, environmental and mechanical performance, cable bend radius, storage reel size, length of cable per reel and packing density are all factors to be taken into consideration.

Other factors include the ease of access to the fibers intermediate the cable ends. Ideally, such access should disturb the minimum number of fibers not being accessed. Additionally, the ease of identification of optical fiber ribbons, the optical fibers and the locations of the ribbons and fibers in the cable are important .

Cables of the three described types with substantially the same number of optical fibers have different characteristics in certain respects. For example, a loose tube cable can have a smaller minimum bend radius and better environmental performance and a greater length of the cable can be received on a standard reel than one or more of the other cable types. Also, a loose tube cable can have a better flexibility than either of the other two cable types and can be easier for craftsmen to use, to identify ribbons or fibers and to install, connect and/or test ("craft-friendly") than the other two cable types.

Another factor of importance is the cross-sectional size of the cables because they are often installed in ducts, and it is desirable to keep the duct size to a minimum and to avoid replacing existing ducts. Ducts are identified by bore diameter, e.g. 1.25 inch (31.7 mm), 1.5 inch (38.1 mm) and 2.0 inch (50.8 mm). Ducts of a 2 inch size are not as common as the

other sizes, and the greatest demand is for cables which can be easily installed in 1.25 inch and 1.5 inch ducts. However, cables which can be easily installed in a 2 inch duct are desirable for some purposes.

A cable must have dimensions such that it can be pulled into and through a duct without damage because of the installation forces applied thereto. Those skilled in the art use a so-called "fill factor" as a measure of the acceptability of a cable to be installed in a duct. "Fill factor" is sometimes defined as the ratio of the cross-sectional area of the cable to the cross-sectional area of the bore of the duct and in the case of a cable and a bore of circular cross-sections, is sometimes defined as the ratio of the cable diameter to the bore diameter. The latter definition will be used herein and in the claims.

From experience, those skilled in the art are aware that the lower the fill factor of a given type of cable, the easier it is to thread or feed a cable through a duct. Generally, the arbitrary, acceptable fill factor is considered to be in the range from 80-85% depending on the cable characteristics, i.e., cross-sectional shape, surface coefficient of friction and cable flexibility. With the usual circular cross-section cable, the plastic of the jacket can be selected to provide a relatively low coefficient of friction with the duct material.

However, cable flexibility depends on the location of the strength member or members with respect to the cable axis and other factors. Thus, a cable with the strength member at the cable axis is more flexible than a cable with one or more longitudinal strength members spaced from the cable axis as is the case with a single tube cable. The flexibility of a slotted core cable is reduced as compared to a central strength member alone, by the thickness of the plastic around the central strength member required to provide the slots which receive the optical fibers. As mentioned hereinbefore, for a given cable size, the loose

tube cable with a central strength member around which buffer tubes are wound has better flexibility than the single tube and slotted core cables.

On the other hand, the flexibility of a loose tube cable decreases with the number of buffer tubes included in the cable, and therefore, the prior art practice of increasing the number of buffer tubes, e.g., to six tubes, to increase the optical fiber count not only increases the cable diameter and hence, the fill factor, but also reduces the cable flexibility. Also, an increase in the number of buffer tubes increases the cost of manufacturing a cable. However, if the normal, substantially circular cable cross-section is desired, the loose tube cable should have more than three buffer tubes.

In addition, certain practices have been adopted in the art as an approach to standardization for ease of installation, splicing, testing, connector types, etc., particularly in North America. For example, it is customary that when optical fiber ribbons are used, each ribbon contains twelve optical fibers, or integral multiples of twelve, optical fibers. Also, as the number of optical fibers in a cable is increased, it is conventional to increase the number of optical fiber ribbons by multiples of twelve. For example, a cable can have: 36 twelve fiber ribbons (432 fibers), 72 twelve fiber ribbons (864 fibers), 144 twelve fiber ribbons (1728 fibers), 108 twenty-four fiber ribbons (2592 fibers), etc.

Because of its desirable characteristics, a loose tube cable with ribbons providing a fiber count greater than 1000 which will not cause a need to depart from prior practices, which is craft friendly and which is easily installed in a 1.5 inch duct is highly desired by the industry.

Similarly, a loose tube cable with ribbons providing a fiber count greater than 2000 which will not cause a need to depart from prior practices, which is craft friendly and which is easily installed in a 2 inch duct is desired by the industry.

The increase in fiber count of such a loose tube cable with optical fiber ribbons cannot be obtained by merely increasing the number of ribbons in a loose tube cable having the required size. Thus, the optical fiber ribbons used to meet the present practices have a standard size and have their own requirements such that the fibers and the ribbons cannot be significantly reduced in size. The buffer tubes containing the ribbons must have a certain relationship between the tube bore and the ribbon stack to prevent damage to the fibers, i.e., the bore size must be such that the ribbons are loosely received in the buffer tubes, and the wall thickness of the tubes cannot be significantly reduced. Similarly, the jacket thickness must not only be sufficient to provide protection to the buffer tube, and hence, the fibers, but also be supported from within to maintain a proper jacket shape.

Summary of the Invention

After substantial study of the problem of providing a loose tube cable with optical fibers in ribbons and a high fiber count, e.g. greater than 1000, which can be received in a 1.5 inch duct with about an 80%-85% fill factor and which will not require changes in the practices adopted by the industry, I have discovered that such a cable can be made with 1728 fibers and, in addition, it is possible to increase the total number of fibers by another 144 fibers to 1872 fibers, which are not in ribbons, if such additional fibers are desired. Thus, as compared to commercially available loose tube cables with optical fiber ribbons which are compatible with a 1.5 inch duct, the number of optical fibers in the cable is substantially increased.

I have also discovered that if the cable of the invention is to be compatible with a larger duct, i.e., a 2 inch duct, a substantial increase in optical fibers, as compared to commercially available loose tube cables, also can be obtained.

In the cable of the invention, optical fiber ribbons of the conventional size, buffer tubes of conventional wall thickness and ratio of bore size to ribbon stack size and a conventional jacket are used, but four buffer tubes, rather than the conventional six buffer tubes, are used for a cable compatible with a 1.5 inch duct. For a cable compatible with a 2 inch duct, the cable of the invention can have four or five buffer tubes, and it is possible to increase the total number of optical fibers by using ribbon stacks with ribbons containing different numbers of optical fibers. The buffer tubes are disposed, each in contact with adjacent tubes, around and in contact with a central strength member structure which, as a result of using four or five buffer tubes, can be reduced in diameter as compared to cables with a greater number of tubes, to provide increased space available for other elements, such as, optical fiber ribbons.

As compared to other cables compatible with a two inch duct, the cable of the invention has a lower fill factor and/or a higher fiber count.

## Brief Description of the Drawings

(to be supplied)

## Detailed Description of Preferred Embodiments

The preferred embodiment of the optical fiber cable of the invention is illustrated in Fig. 1, but before describing the cable 1 illustrated in Fig. 1, the difficulties in designing an optical fiber cable which can be fed in a 1.5 inch (38.1 mm) duct and which has substantially in excess of 1000 optical fibers must be considered. Reference to the schematic diagram of Figs. 2-4 will be made for this purpose.

The space within the cable jacket 2 is most efficiently used for containing optical fibers when the buffer tubes 3 contact each other and extend from the outer surface of the

1. An elongated optical fiber cable with a longitudinal axis and with more than 1000 optical fibers, said cable having a fill factor not greater than about 85% in a two in. duct and said cable comprising:

a central strength member structure coaxial with the longitudinal axis;

a plurality of longitudinally extending buffer tubes disposed around the central strength member structure in a single layer with each tube in contact with a pair of adjacent tubes and in contact with the strength member structure, the number of buffer tubes being greater than three and less than six and each tube having a bore of a predetermined size;

a plurality of optical fiber ribbons in a stack in the bore of each of said tubes, each stack substantially filling, but being loosely received, in the bore of the tube in which the stack is received and each ribbon comprising a plurality of optical fibers in side-by-side relation and wherein the total number of optical fibers in the plurality of buffer tubes is greater than 1000; and

a jacket encircling the plurality of buffer tubes.

2. An optical fiber cable as set forth in claim 1 wherein the number of buffer tubes is four, the total number of optical fibers is greater than 2000 and the fill factor is not greater than about 80% in a two inch duct.

3. An optical fiber cable as set forth in claim 2 wherein each of the optical fiber ribbons in a stack received in at least one buffer tube contains the same number of optical fibers.

4. An optical fiber cable as set forth in claim3 wherein each of the ribbons in a stack received in at least one buffer tube contains twenty-four optical fibers.

5. An optical fiber cable as set forth in claim 2 wherein some of the optical fiber ribbons in a stack received in at least one buffer tube contain fewer optical fibers than other optical fiber ribbons in the same stack.

6. An optical fiber cable as set forth in claim 5 wherein some of the optical fiber ribbons contain twelve optical fibers, some of the optical fiber ribbons contain twenty-four optical fibers and the remainder of the optical fiber ribbons contain thirty-six optical fiber ribbons.

7. An optical fiber cable as set forth in claim 2 wherein the fill factor is not greater than about 75%.

8. An optical fiber cable as set forth in claim 1 wherein the number of buffer tubes is four, the total number of optical fibers is greater than 1500 and the fill factor is not greater than about 85% in a one-and one-half inch duct.

9. An optical fiber cable as set forth in claim 8 wherein there are interstices within the jacket which are intermediate pairs of buffer tubes and also intermediate such pairs of buffer tubes and the jacket and wherein there are additional optical fibers in at least one of the interstices.

10. An optical fiber cable as set forth in claim 9 wherein the total number of optical fibers is at least 1700.

11. An optical fiber cable as set forth in claim 1 wherein the number of buffer tubes is five, the total number of optical fibers is greater than 2000 and the fill factor is not greater than about 80% in a two inch duct.

12. An optical fiber cable as set forth in claim 11 wherein each of the optical fiber ribbons in a stack received in at least one buffer tube contains the same number of optical fibers.

13. An optical fiber cable as set forth in claim 12 wherein each of the ribbons in a stack received in at least one buffer tube contains twenty-four optical fibers.

14. An optical fiber cable as set forth in claim 11 wherein some of the optical fiber ribbons in a stack received in at least one buffer tube contain fewer optical fibers than other optical fiber ribbons in the same stack.

15. An optical fiber cable as set forth in claim 14 wherein some of the optical fiber ribbons contain twelve optical fibers, some of the optical fiber ribbons contain twenty-four optical fibers and the remainder of the optical fiber ribbons contain thirty-six optical fiber ribbons.

16. An optical fiber cable as set forth in claim 1 wherein the number of buffer tubes is five, the total number of optical fibers is greater than 2600 and the fill factor is not greater than about 80% in a two inch duct.

17. An optical fiber cable as set forth in claim 1 wherein the central strength member structure comprises a core of high tensile strength material and an encircling layer of jacketing material.

18. An optical fiber cable as set forth in claim 1 wherein the central strength member structure comprises a core of high tensile strength material and an encircling layer of water blocking material.

19. An optical fiber cable as set forth in claim 1 further comprising water blocking material within the jacket.

20. An optical fiber cable as set forth in claim 1 further comprising flexible strength members within the jacket and spaced from the central strength member structure.

21. An optical fiber cable as set forth in claim 1 wherein the buffer tubes are disposed around the central strength member structure in reverse alternating lay.